Marine Research

SCOTTISH HOME DEPARTMENT

Marine Research
1957 No. 1

Herring Rearing—III
The Effect of Temperature and other Factors on Myotome Counts

By J. H. S. BLAXTER, M.A.

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE

FOUR SHILLINGS NET

The following Marine Research publications are in continuation of those previously issued by the Fishery Board for Scotland, whose functions were transferred in 1939 to the Scottish Home Department:

SCIENTIFIC INVESTIGATION SERIES

1949 1. Distribution of Thaliacae (Salps snd Doliolids) in Scottish Waters, 1920 to 1939.
By J. H. Fraser, M.Sc., Ph.D., F.R.S.E. Price 2s. (2s. 2d.)

MARINE RESEARCH SERIES

1952 1. Statistics of the Scottish Halibut Fishery, 1930-1949.
By A. D. McIntyre, B.Sc. Price 4s. (4s. 2d.)

2. The Chaetognatha and other Zooplankton of the Scottish Area and their value as Biological Indicators of Hydrographical Conditions.
By J. H. Fraser, M.Sc., Ph.D., F.R.S.E. Price 7s. 6d. (7s. 9d.)

3. The Food of Halibut from North Atlantic Fishing Grounds.
By A. D. McIntyre, B.Sc. Price 4s. (4s. 2d.)

4. Haddock Bionomics—1. The State of the Haddock Stocks in the North Sea, 1946-50 and at Faroe, 1914-50.
By B. B. Parrish, B.Sc., and R. Jones, B.Sc. Price 5s. (5s. 2d.)

1953 1. The Occurrence of Lemon Sole Larvæ in the Scottish Plankton Collections of 1929, 1930 and 1931.
By B. B. Rae, M.A., B.Sc., Ph.D. Price 7s. (7s. 3d.)

1954 1. Some Observations on the Distribution, Biology and Exploitation of the Norway Lobster (*Nephrops norvegicus* L.) in Scottish Waters.
By H. J. Thomas, B.Sc., Ph.D. Price 2s. 6d. (2s. 8d.)

2. The Food of the Whiting and a Comparison with that of the Haddock.
By R. Jones, B.Sc. Price 7s. (7s. 3d.)

1955 1. The Plankton of the Waters Approaching the British Isles in 1953.
By H. J. Fraser, D.Sc., Ph.D., F.R.S.E. Price 2s. 6d. (2s. 8d.)

2. Observations on the Recaptures of Tagged Lobsters in Scotland.
By H. J. Thomas, B.Sc., Ph.D. Price 2s. 6d. (2s. 8d.)

3. Herring Rearing—I. The Storage of Herring Gametes.
By J. H. S. Blaxter, B.A. Price 2s. 6d. (2s. 8d.)

1956 1. The Effect of Electric Fields on Marine Fishes.
By Lt. Cdr. (Sp.) B. McK. Bary, M.Sc., Ph.D., R.N.Z.N. Price 7s. (7s. 3d.)

2. The Whiting (*Gadus merlangus* L.) in the North Sea.
By R. W. Ellis, B.Sc., and R. Jones, B.Sc. Price 5s. (5s. 2d.)

3. The Food and Feeding Habits of the Lemon Sole.
By Bennet B. Rae, M.A., B.Sc., Ph.D. Price 6s. 6d. (6s. 8d.)

4. Eggs and Larvæ of Haddock (*Gadus aegelfinus* L.) at Faroe.
By Alan Saville, B.Sc. Price 5s. (5s. 2d.)

5. Herring Rearing—II. The Effect of Temperature and other Factors on Development.
By J. H. S. Blaxter, M.A. Price 4s. (4s. 2d.)

1957 1. Herring Rearing—III. The Effect of Temperature and other Factors on Myotome Counts.
By J. H. S. Blaxter, M.A. Price 4s. (4s. 2d.)

(Prices in brackets include postage)

SCOTTISH SEA FISHERIES STATISTICAL TABLES

These tables, which are published annually, give full information about the weight and value of fish landed, analysed by species, means of capture and areas of capture.

PRACTICAL HINTS FOR LOBSTER FISHERMEN

An illustrated booklet full of useful hints for the lobster fisherman operating on a commercial scale, or for the crofter fisherman.
Price 1s. 3d. (1s. 5d.)

Obtainable from HER MAJESTY'S STATIONERY OFFICE
at the address on page 4 of cover or through any bookseller

SCOTTISH HOME DEPARTMENT

MARINE RESEARCH
1957 No. 1

Herring Rearing—III

The Effect of Temperature and other Factors on Myotome Counts

by J. H. S. BLAXTER, M.A.

EDINBURGH: HER MAJESTY'S STATIONERY OFFICE
1957

CONTENTS

	Page
INTRODUCTION	3
METHODS	
General	3
Myotome Counting	4
RESULTS	
General	5
Experiments—Mean Myotome Counts at Hatching	8
„ —Mean Myotome Counts at Yolk Sac Absorption ..	11
Myotome and Vertebral Counts of Larvae Caught at Sea	12
Myotome Counts of Cross-Fertilised Larvae	13
DISCUSSION	13
ACKNOWLEDGEMENTS	14
SUMMARY	15
REFERENCES	16

THE EFFECT OF TEMPERATURE AND OTHER FACTORS ON MYOTOME COUNTS

INTRODUCTION

The Atlantic herring (*Clupea harengus*, L) may be divided into groups by a statistical analysis of its meristic characters. The most commonly used character is the number of vertebrae which, due to individual variability, is only of value in identifying a group when the mean count of a sample of fish is taken. There are two main groups of herring, one which spawns in the spring (with a mean vertebral count of about 56·9–57·3) and the other in the autumn and winter (with a count of 56·3–56·6). Each of these groups has been divided into numerous subgroups.

It is of considerable importance to find out whether the differences between mean vertebral counts are a product of the genotype, or whether they are determined to some extent by environmental conditions during early life and indeed, into which taxonomic category the groups should be placed. Heincke (1898) the pioneer of herring racial work and Schnakenbeck (1931) were of the former opinion while Johansen 1924), Lissner (1934) and Davis (1936) favoured the latter view, one which is supported by most other workers during the past twenty years.

The problem may be approached by rearing herring larvae under controlled conditions and by correlating meristic characters with environmental conditions at and after spawning. This latter method has been used in the Pacific herring (*Clupea pallasii*) by Rounsefell (1930), Rounsefell and Dahlgren (1932), and Tester (1937, 1938) who found in various ways an inverse correlation of mean vertebral count with temperature. In the Atlantic herring Runnstrøm (1933) showed that the mean vertebral counts of O-brood herring from different areas on the Norwegian coast were negatively correlated with the temperatures in those areas in March. Later (1941) he showed a similar correlation amongst spring spawners from widely different areas in the North Sea. Bückmann (1950) found a negative correlation for autumn spawned herring larvae in the North Sea.

The experimental approach involves the initial problem of rearing herring to a stage where the vertebrae may be counted (i.e. to a length of at least 30 mm). Successful attempts have been made by Meyer (1878), Schach (1939) and Dannevig (1948), but the environmental conditions, particularly temperature, were not adequately controlled to make meristic counts worth while. Hempel (1953), however, has reported a correlation between temperature and myotome count in herring rearing experiments (p. 14). There is abundant experimental evidence of the plasticity of meristic characters in other fish due to differing environmental conditions such as temperature, salinity and oxygen and carbon dioxide tensions in the early stages (see review by Tåning, 1952). In particular, Tåning's (1944) work on the effect of temperature on mean vertebral count in the sea trout, *Salmo trutta trutta*, should be mentioned.

It was decided (in ignorance of Hempel's work) that a fresh attempt should be made to rear herring larvae under controlled conditions. In case the project should prove unsuccessful, myotome counts were also to be made. Myotomes are visible at a much earlier stage than vertebrae, and can be counted before the critical period when the larvae change from yolk sac to external food sources. There is good reason to suppose that myotome and vertebral counts are related (p. 12).

The results given here refer to the data obtained on myotome counts, rearing work beyond the yolk sac stage as yet being unsuccessful.

METHODS

General

The apparatus, material and methods used were the same as those described in Part II of the series (Blaxter, 1956).

Briefly the experiments were designed to test the effect of incubation temperature on myotome counts of larvae of different parentage and spawning type after artificial fertilisation. At each temperature a combination of three parents (A, B and C) was used as in Table I.

TABLE I

The experimental plan

	Tank 1	Tank 2	Tank 3	Tank 4
	Temp. 1 (about 5·5°C.)	Temp. 2 (about 8·5°C.)	Temp. 3 (about 11·5°C.)	Temp. 4 (about 14·5°C.)
Compartment 1	A × B	A × B	A × B	A × B
Compartment 2	B × C	B × C	B × C	B × C

In the first successful experiments (autumn, 1953), three tanks at temperatures of about 8·5°C, 11·5°C and 14·5°C were used. Later (spring, 1954 and 1955 and autumn, 1954), a fourth tank at about 5·5°C was added, while in autumn, 1955, only one tank at about 11·5°C was used. The temperature range extended from the average temperature at spawning in the spring (5°C–8°C) to that in the autumn (9°C–14°C). If the temperature at spawning is responsible for the difference in mean vertebral count of spring and autumn spawners then the mean myotome counts should vary at different temperatures.

Details of any variation in other conditions (salinity, oxygen tension) are given in the previous paper. They are not considered to have affected the results.

Myotome Counting

Samples of 30–50 larvae for myotome counting were removed from each tank at the time when 50% had hatched and later when 50% had reached the end of the yolk sac stage (i.e. when all the yolk was absorbed), thus ensuring that the larvae were at the same stage of development. (These two stages will be referred to as the 50% hatching and 50% yolk sac absorption stages.) The larvae were anaesthetised in 1% magnesium chloride or 2% urethane and fixed in 4% formol-saline. Later they were lightly stained with 0·1% toluidine blue and the myotomes counted under a monocular microscope using crossed polaroids. In this way maximum contrast between myotomes and myocommata was obtained. This is particularly important in the posterior region.

Total myotome counts were made from the first to the last *complete* myotome, i.e. the regions anterior and posterior to the first and last complete myocomma were not counted. This eliminated a number of incomplete myotomes immediately behind the head. Because total counts were sometimes difficult, and so that comparison could be made with Lebour (1921), who used anal counts for distinguishing different species of clupeoid larvae, counts were also made to the point where the gut turns downwards from the ventral body wall to form the anus (anal counts).

Apart from experimental material, myotomes were also counted in spring and autumn spawned larvae caught at sea by plankton net at the end of the yolk sac stage.

Counts were also made on larvae obtained from crossing a female autumn spawner with a male spring spawner, after storing the spermatozoa of a spring spawner for about six months until the autumn spawning season (Blaxter, 1955).

In order to relate myotome to vertebral counts, larvae from the sea, 30–40 mm in length, were obtained. Their vertebrae had become ossified and were stained with alizarin using a modification of Tåning's (1944) technique. (Staining was carried out for 72 hours without prior bleaching.). Myotome and vertebral counts were then made using crossed polaroids with the larvae squashed between microscope slides.

RESULTS

General

(1) *Variation in total number of myotomes*

The total number of myotomes at 50% absorption of the yolk sac varied usually from 59 to 63, but in one case was as high as 67: numbers much higher than those of Fage (1920) and Lebour (1921). This may be due to the improved technique of counting under crossed polaroids. After natural death

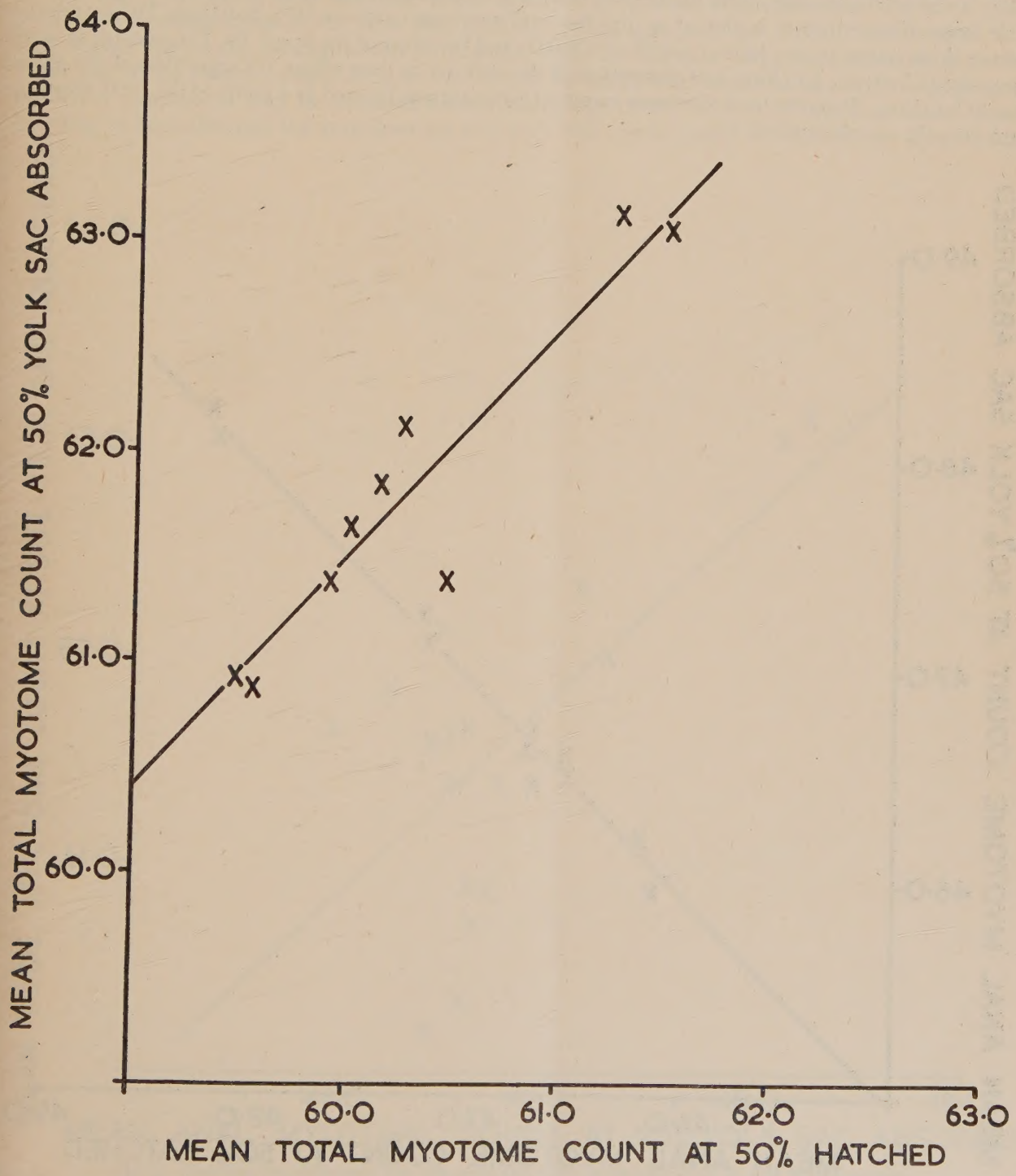


Fig. 1 Showing the increase in visible myotomes between hatching and yolk sac absorption.

the larvae shrank considerably and counting was not possible. This necessitated anaesthetising the larvae and then fixing them in formol-saline. In a few cases the myotomes were very irregular, the myocommata being uneven and incomplete.

The number of visible myotomes increases between hatching and absorption of the yolk sac, but it has not been possible to find out whether more myotomes become visible after absorption of the yolk sac. In Fig. 1 the total myotome count at the 50% yolk sac absorption stage, from samples of larvae over the whole range of experiments, is plotted against the total myotome count on 50% hatching. The correlation between these counts is very high; $r=0{\cdot}94$ ($P<0{\cdot}001$) and the slope of the line 1·10. The average increase in myotomes between hatching and absorption of the yolk sac is then about 1·5 regardless of the actual value at hatching. Thus the total myotome count on hatching can be used as a guide to the total myotome count on yolk sac absorption.

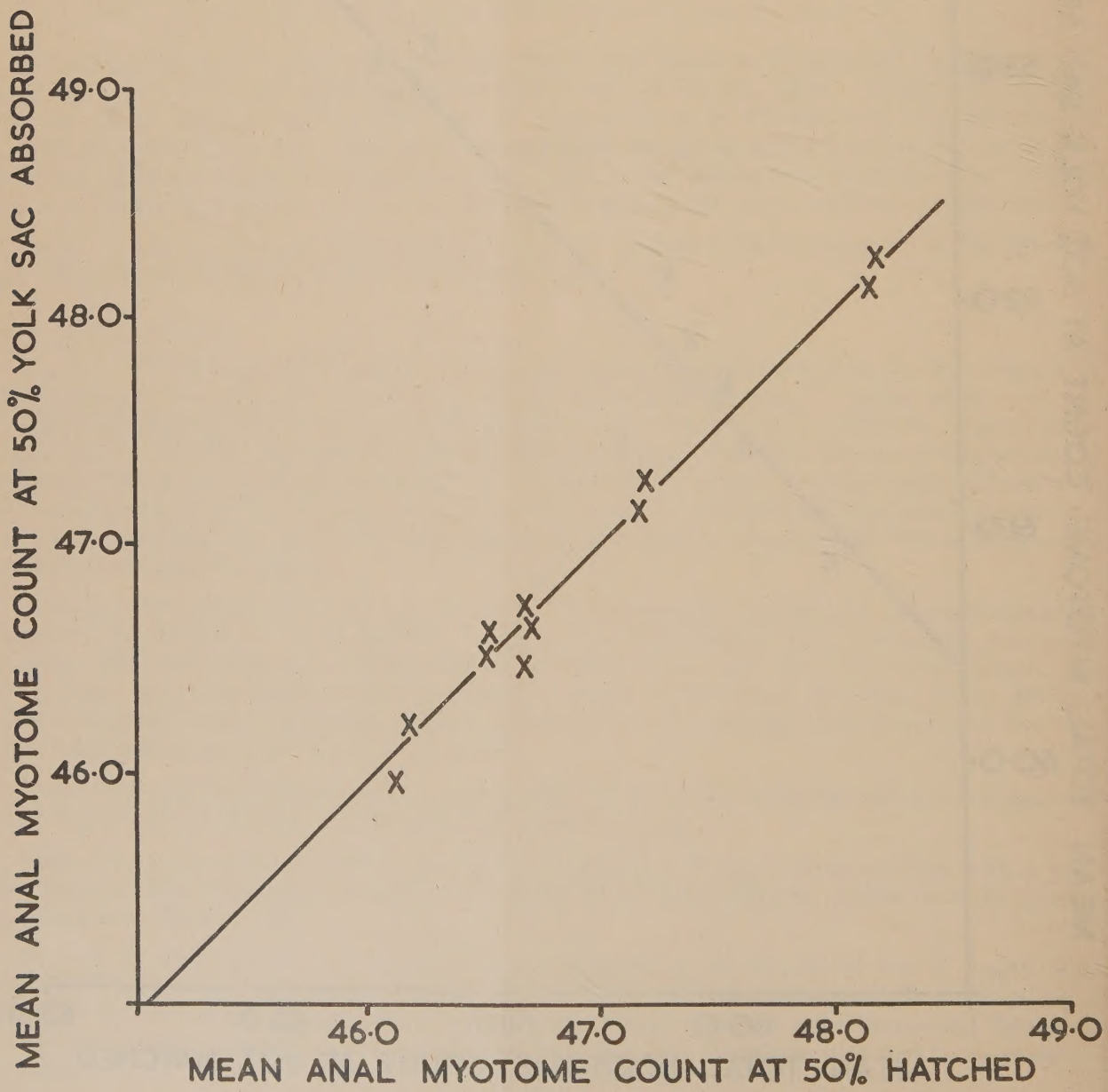


Fig. 2 Showing anal counts at hatching and yolk sac absorption.

(2) *Variation in number of myotomes to anus*

The anal counts do not seem to vary during development as far as the end of the yolk sac stage. This is shown in Fig. 2 where the mean anal count at the 50% yolk sac absorption stage is plotted against mean anal count at 50% hatching ($r=0{\cdot}99$, $P<0{\cdot}001$, slope of line 0·99). There does not appear to be any migration of the anus between these stages, which is in agreement with Lebour (1921).

(3) *The relationship between anal and total myotome counts*

In Fig. 3 the mean total myotome count at the 50% yolk sac absorption stage is plotted against mean anal myotome count at the same time ($r=0{\cdot}68$, $P<0{\cdot}01$, slope of line 0·95). The data show a very wide scatter but on the average it can be said that there are about 15 myotomes posterior to the anus at the end of the yolk sac stage. Thus an estimate of the mean total myotome count of a sample or in a particular experiment may be obtained from a knowledge of the mean anal myotome count either at hatching or later (because the anus does not migrate). This can be useful if the posterior end of the body

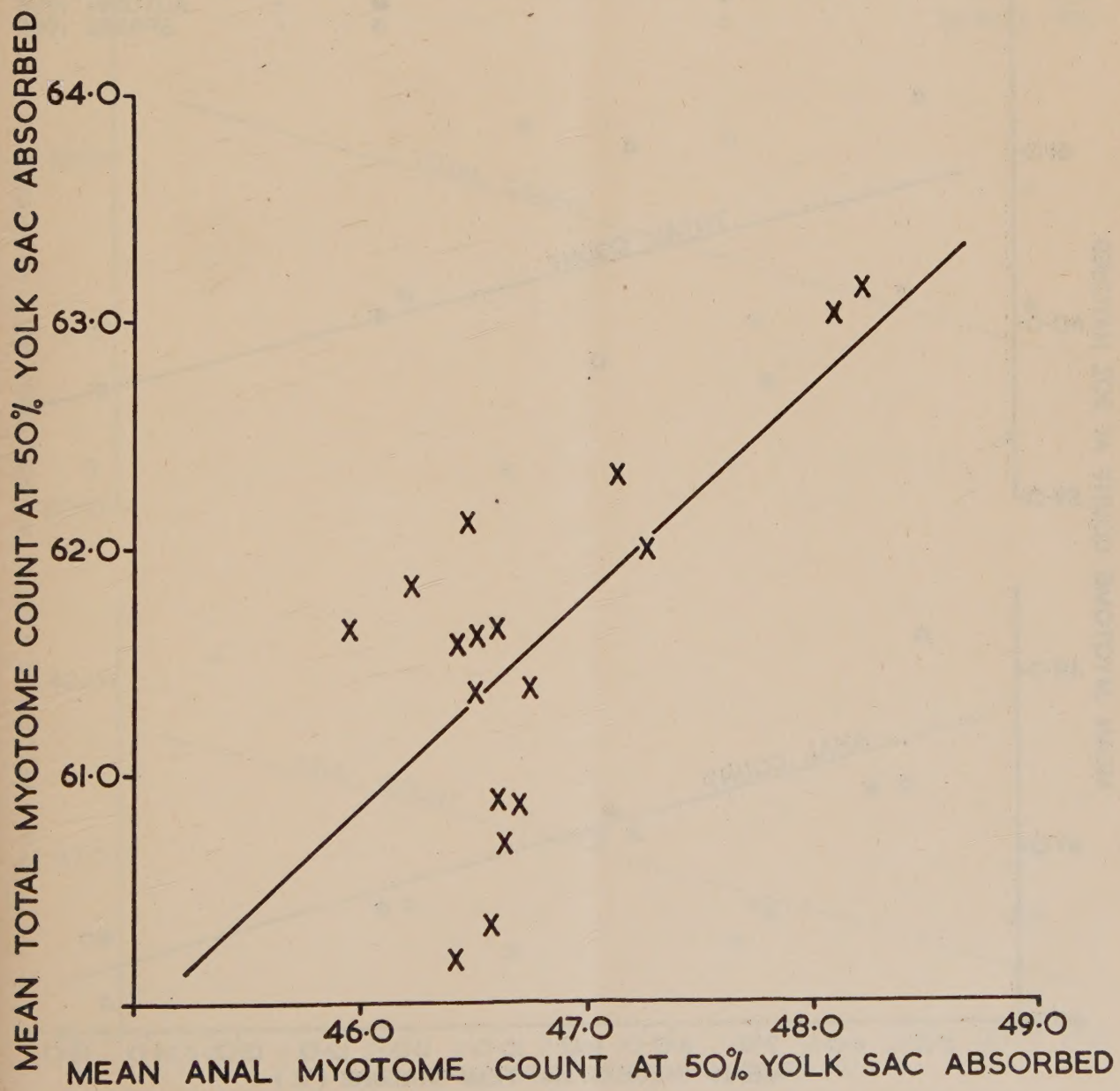


Fig. 3 Showing the difference between anal and total myotome counts at yolk sac absorption.

is obscured or if the larvae die before the end of the yolk sac stage. The slope of the line indicates that, up to 50% yolk sac absorption, any variation in visible total myotome count with temperature is the property of the *trunk region* (anterior to the anus) as the number of visible myotomes posterior to the anus tends to be constant (i.e. about 15). Ford (1933) found that variation in vertebrae in adult herring is mainly in the 'tail'. It is difficult to compare these results as it is not clear what part of the larval body can be compared with the 'tail' section as described by Ford. It may be that a variation appears in the post-anal region when the anus migrates forward at a later stage, as described by Lebour (1921).

Experiments—Mean Myotome Counts at Hatching

The results are shown in Fig. 4 and Tables III, IV and V. No data are available for autumn, 1953, when counts were made at 50% yolk sac absorption only.

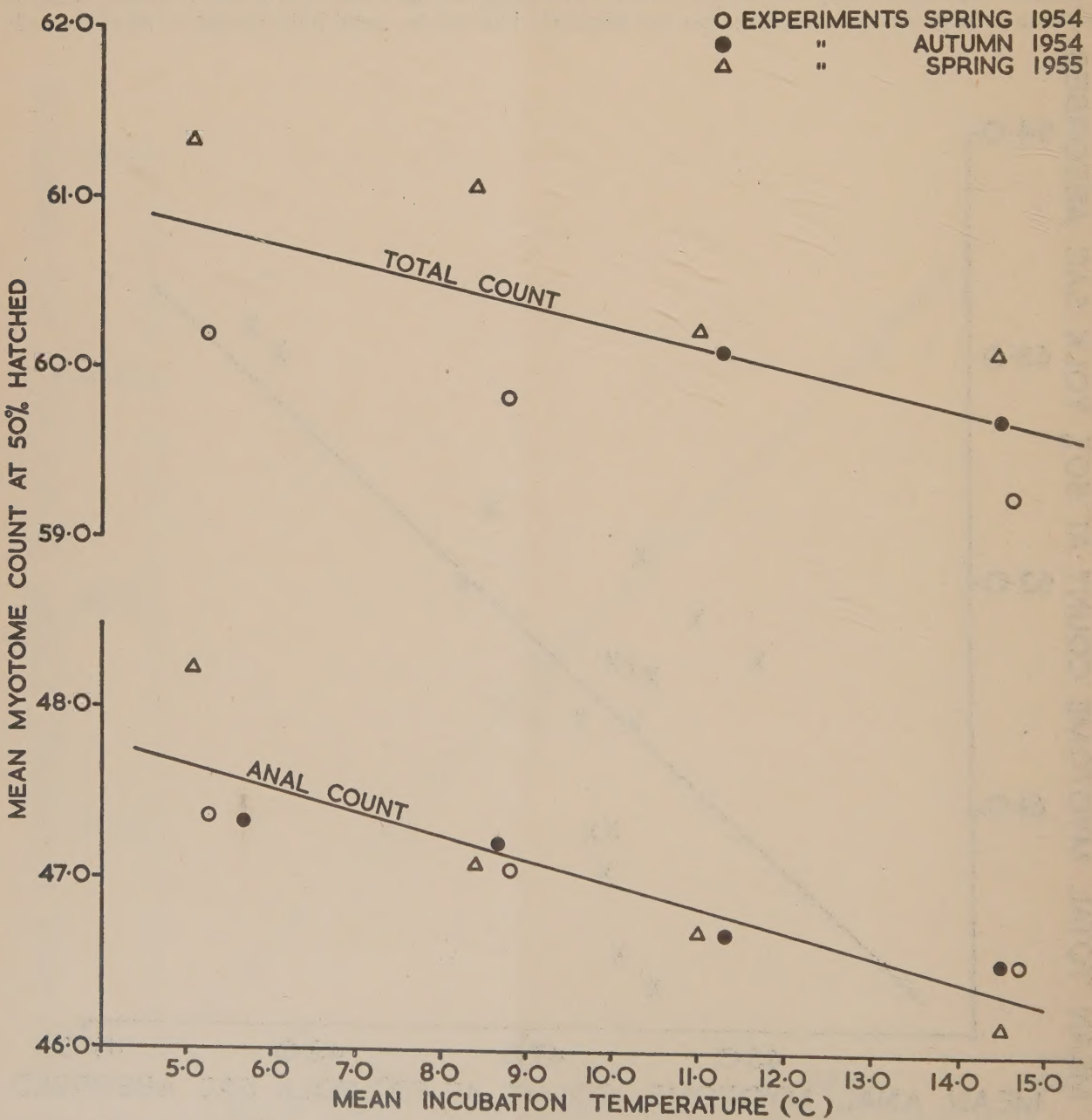


Fig. 4 Showing the effect of temperature on anal and total mean myotome counts at hatching.

(*1*) *Anal counts at 50% hatched*

In spring 1954 there is a highly significant difference ($P<0{\cdot}001$) between mean anal counts at different temperatures (ignoring temperature 11·54°C, where numbers are too few), but no real difference between parents.

In autumn, 1954, and spring, 1955, there are again highly significant differences between mean anal count at different temperatures ($P<0{\cdot}001$ for both seasons), but no significant parental differences.

The general relationship over the three seasons is shown by a regression line in Fig. 4. As no parental differences were detected each point on the graph represents the weighted average for both sets of parents at each temperature. The regression is highly significant ($F=37{\cdot}7$ with 1 and 9 d.f., $P<0{\cdot}001$) and the line has a slope −0·137.

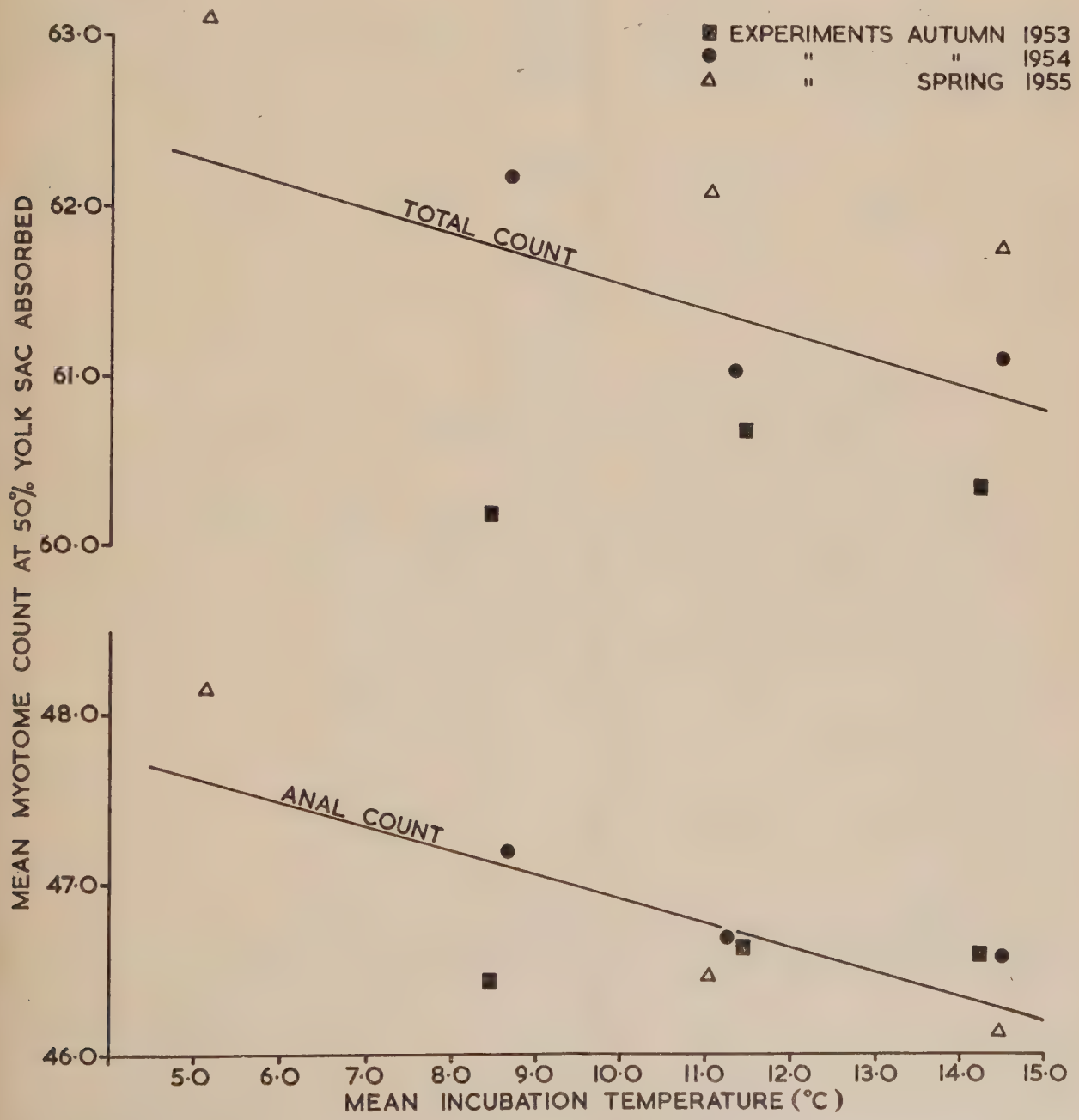


Fig. 5 Showing the effect of temperature on anal and total mean myotome counts at yolk sac absorption.

(2) *Total counts at 50% hatched*

In spring, 1954, there is a significant difference ($P<0{\cdot}05$) between mean total myotome count at different temperatures (ignoring temperature 11·54°C and combining parents).

In autumn, 1954, total counts are only available at 11·31°C and 14·51°C, due to early hatching at the two lower temperatures which made the posterior myotomes obscure. The difference arising either from temperatures or parentage is not significant.

In spring, 1955, there is a highly significant difference ($P<0{\cdot}001$) between the total myotome counts at different temperatures, but no difference between parents.

The general relationship between total myotome count at 50% hatched is shown in Fig. 4. The regression line is again obtained from points which represent the weighted mean for both sets of parents (as no parental differences can be shown). The regression is not significant ($F=6{\cdot}8$ with 1 and 7 d.f.); it has a slope of −0·122.

TABLE II

(Autumn, 1953)

Mean Incubation Temperature to Yolk Sac Absorption		8·45°C.	11·43°C.	14·23°C.
Vertebral Count of Parents		56 × 57	56 × 57	56 × 57
Mean Myotome Counts at 50% Yolk Sac Absorbed	Anal	46·43 (43) ±0·080	46·62 (60) ±0·069	46·58 (45) ±0·079 degrees of freedom=145
	Total	60·17 (41) ±0·133	60·68 (41) ±0·133	60·36 (42) ±0·132 d.f. =121

TABLE III

(Spring, 1954)

Mean Incubation Temperature to Hatching		5·27°C.	8·82°C.	11·54°C.	14·68°C.
Vertebral Count of Parents		56 × 57 57 × 57	56 × 57 57 × 57	56 × 57 57 × 57	56 × 57 57 × 57
Mean Myotome Count at 50% Hatched	Anal	47·42 (31) 47·26 (19) 47·36 (50) ±0·073	47·09 (33) 46·89 (9) 47·05 (42) ±0·080	— 46·69 (8)	46·54 (25) 46·48 (20) 46·51 (45) ±0·077 d.f.=131
	Total	60·0 (4) 60·5 (2) 60·17 (6) ±0·378	60·2 (5) 59·5 (6) 59·82 (11) ±0·279	— 59·0 (4)	59·18 (22) 59·29 (17) 59·23 (39) ±0·148 d.f.=53

TABLE IV

(Autumn, 1954)

Mean Incubation Temperature to Yolk Sac Absorption (To Hatching in Brackets)		5·68°C. (5·70)	8·66°C. (8·66)	11·31°C. (11·28)	14·51°C. (14·53)
Vertebral Count of Parents		56 × 57 56 × 56	56 × 57 56 × 56	56 × 57 56 × 56	56 × 57 56 × 56
Mean Myotome Count at 50% Hatched	Anal	47·36 (22) 47·33 (26) 47·34 (48) ±0·079	47·19 (18) 47·22 (44) 47·21 (62) ±0·068	46·67 (29) 46·72 (30) 46·69 (59) ±0·071	46·53 (35) 46·53 (34) 46·53 (69) ±0·066 d.f.=230
	Total	— — —	— — —	59·55 (20) 60·48 (25) 60·07 (45) ±0·173	59·45 (33) 59·90 (31) 59·67 (64) ±0·145 d.f.=107
Mean Myotome Count at 50% Yolk Sac Absorbed	Anal	— —	47·13 (8) 47·25 (6) 47·18 (14) ±0·180	46·70 (25) 46·67 (15) 46·69 (40) ±0·106	46·62 (26) 46·50 (25) 46·56 (51) ±0·094 d.f.= 99
	Total	— —	62·33 (6) 62·00 (5) 62·18 (11) ±0·301	60·88 (24) 61·38 (13) 61·05 (37) ±0·164	60·92 (26) 61·36 (25) 61·14 (51) ±0·140 d.f.=93

TABLE V

(Spring, 1955)

Mean Incubation Temperature to Yolk Sac Absorption (To Hatching in Brackets)		5·10°C. (5·15)	8·43°C. (8·49)	11·01°C. (11·13)	14·48°C. (14·53)
Vertebral Count of Parents		57 × 57 56 × 57	57 × 57 56 × 57	57 × 57 56 × 57	57 × 57 56 × 57
Mean Myotome Count at 50% Hatched	Anal	48·23 (26) 48·19 (13) 48·22 (39) ±0·083	47·11 (37) 47·06 (34) 47·08 (71) ±0·061	46·68 (31) 46·71 (31) 46·69 (62) ±0·066	46·19 (21) 46·12 (13) 46·16 (34) ±0·089 d.f.=198
	Total	61·26 (19) 61·50 (8) 61·33 (27) ±0·157	60·96 (27) 61·15 (27) 61·06 (54) ±0·111	60·25 (16) 60·11 (18) 60·18 (34) ±0·140	60·16 (19) 60·00 (14) 60·09 (33) ±0·142 d.f.=140
Mean Myotome Count at 50% Yolk Sac Absorbed	Anal	48·21 (28) 48·08 (24) 48·15 (52) ±0·074	— 47·5 (2) —	46·47 (19) 46·33 (3) 46·45 (22) ±0·113	46·21 (24) 45·96 (11) 46·13 (35) ±0·090 d.f.=103
	Total	63·14 (28) 63·05 (19) 63·11 (47) ±0·116	— 63·0 (1) —	62·11 (19) 62·0 (3) 62·09 (22) ±0·170	61·83 (24) 61·64 (11) 61·77 (35) ±0·134 d.f.=98

Experiments—Mean Myotome Counts at Yolk Sac Absorption

The results are shown in Fig. 5 and Tables II, IV and V. No data are available for spring, 1954, as the larvae did not survive the yolk sac stage.

(1) *Anal counts at 50% yolk sac absorption*

In autumn, 1953, only three temperatures and one set of parents were used (8·45°C, 11·43°C and 14·23°C) and the mean anal myotome count is highest at the intermediate temperature. There is no significant difference between the mean anal myotome counts.

In autumn, 1954, data are lacking for the lowest temperature 5·68°C, but there is a significant difference between the mean anal myotome counts at the remaining three temperatures ($P<0·05$), and no significant difference between parents.

In spring, 1955, there is a highly significant difference between mean anal myotome counts at different temperatures ($P<0·001$, excluding temperature 8·43°C where there are insufficient data) but there is again no difference between parents.

The results for the three seasons, considering parents together, are combined in the regression line shown in Fig. 5. The regression is significant ($F=11·2$ with 1 and 7 d.f., $P<0·05$) and the line has a slope −0·145.

(2) *Total counts at 50% yolk sac absorption*

In autumn, 1953, there is a significant difference between mean total myotome counts at the three temperatures ($P<0·05$), the mean total myotome count being highest at the intermediate temperature.

In autumn, 1954, the difference between mean total myotome counts is significant at different temperatures ($P<0·01$, excluding temperature 5·68°C where there are no data) but there is no parental difference.

In spring, 1955, the difference is highly significant ($P<0·001$, excluding 8·43°C where only one count was available) between temperatures but not between parents.

The regression line combining these data, parents again being taken together, is shown in Fig. 5 and is not significant ($F=2·2$ with 1 and 7 d.f.). Its slope is −0·146.

Myotome and Vertebral Counts of Larvae Caught at Sea

Schnakenbeck (1929) was of the opinion that myotome counts and vertebral counts were related in herring. To examine this relationship quantitatively larvae from spring and autumn spawnings were caught at sea by oblique hauls of a plankton net (60 mesh silk) one metre in diameter. Larvae at the end of the yolk sac stage (10–12 mm long) were picked out for myotome counts. The results are given in Table VI.

TABLE VI

Myotome counts of autumn and spring spawned larvae from the sea

		Autumn Spawned	Spring Spawned	S.E. of difference	Degrees of freedom
Mean Myotome Count	Anal	46·66 (49)	46·83 (49)	±0·109	96
	Total	60·50 (46)	60·96 (46)	±0·161	90

There is a significant difference between the two groups; for anal counts $t=4·59$ ($P<0·001$) and for total counts $t=2·86$ ($P<0·01$). It would seem that the myotome count is four greater than the vertebral count (i.e. the mean vertebral counts would be 56·50 and 56·96—values which might be expected from autumn and spring spawned herring off eastern Scotland.

However when myotome and vertebral counts are compared in the same larvae a different result is obtained. Table VII shows the vertebral and myotome counts in 38 autumn spawned larvae (30–40 mm long) obtained by plankton net from the sea.

TABLE VII

Vertebral and myotome counts compared. (Larvae from sea)

Number	Total Vertebral Count	Total Myotome Count
2	55	58
19	56	59
14	57	60
1	57	61
2	58	61
38	56·45	59·47

With one exception, the vertebral count is three less than the myotome count. It cannot be certain whether the difference of three in the counts is the true figure, as the vertebrae are not formed at a stage when the myotomes are still completely clear. Thus while myotome and vertebral counts are obviously related, it cannot be said at present whether there are three or four more myotomes than vertebrae. Four seems the more likely figure.

Myotome Counts of Cross-Fertilised Larvae

In autumn, 1955, the eggs of an autumn spawning female were fertilised with sperm which had been stored for six months from the spring of 1955. The cross-fertilised eggs and those of a control (where both parents were fish spawning in autumn 1955) were incubated at 11·5°C. Myotome counts were made on hatching and the results are given in Table VIII.

TABLE VIII

Myotome counts of cross-fertilised larvae

		♀ Autumn × ♂ Autumn 1955 (57)	1955 (56)	♀ Autumn × ♂ Spring 1955 (57)	1955 (56)	S.E. of difference	Degrees of freedom
Mean Myotome Count at 50% hatched	Anal	46·88 (20)		46·80 (20)		±0·233	38
	Total	59·93 (14)		59·71 (14)		±0·393	26

There is no significant difference in the results; for anal counts, $t=0·32$ and for total counts $t=0·56$. This indicates that there is no obvious genetical effect on the myotome counts due to the male parent.

DISCUSSION

The most consistent factor which alters the myotome counts in these experiments is temperature, high incubation temperatures generally decreasing the myotome count. The effect of temperature is uniform when different methods of counting myotomes are used (i.e. anal and total counts at hatching and then at yolk sac absorption, when plotted against temperature, give regression lines with slopes of −0·137, −0·122, −0·145 and −0·146 respectively).

Within the limits of the experiments, there appears to be no consistent effect of parent on the myotome count of its offspring. The effect of race is more difficult to judge. While there is no apparent effect in cross-fertilisation experiments, an examination of Tables IV and V, in particular, shows that the range of mean myotome count is much greater in spring, 1955, than in autumn, 1954, though this is not shown in spring, 1954.

The experiments do, however, show that there is considerable plasticity in the myotome counts (and therefore vertebral counts) due to incubation temperature. The difference of vertebral count found in spring and autumn spawning herring may then be wholly due to environmental factors. The experiments indicate the probability that there is a difference in response to temperature, the spring spawner reacting more markedly to the extremes of temperature used. In the middle of the range (8·5°C–11·5°C) there is very little difference in the mean myotome count of the different groups.

The mean total myotome counts at absorption of the yolk sac range from about 60·0 to 63·0. The relationship between myotome and vertebral count has not been quantitatively established. Where myotomes and vertebrae could be counted together, the myotomes were three more than the vertebrae but the myotome counts made on samples of larvae from the sea, before the vertebrae were formed, indicated that there were four more myotomes than vertebrae. Thus the vertebral counts in the experiments might range from 56 to 59 or 57 to 60. These are much higher ranges than those found naturally (p. 3) or shown in the counts made on larvae from the sea, even allowing for the wide range of temperature used in the experiments. This may be due to development under laboratory conditions, as Gabriel (1944) found that laboratory reared killifish had higher mean vertebral counts than was normal.

Gabriel has accounted for the effect of temperature on meristic characters by developing the theory that temperature differences affect the temperature relations between processes controlling growth and differentiation. Low temperatures retard differentiation relatively more than growth so allowing, for instance, a greater formation of presumptive myotome tissue before the segments are laid down.

There appear, then, to be various factors operating in the control of myotome and therefore vertebra formation in herring. Within broad limits the number of vertebrae is presumably inherited. (For example the sprat, *Clupea sprattus*, has an average of about eight less vertebrae than herring). This inherent effect brings the vertebrae to a range within which number is controlled by temperature during early development. The genotype may in some way vary the response to temperature. Superimposed on these three factors is that of natural variability for no sample contains fish all with the same vertebral count.

If these results are compared with Hempel's (1953), it is seen that his mean myotome counts, though inversely correlated with temperature, lie between 56·31 and 57·80 for larvae of parents from a spring spawning group, and are thus well below the mean myotome counts shown above. This difference is probably partly due to counting technique and possibly due to the low mean vertebral count found in this group (55·2, personal communication).

ACKNOWLEDGEMENTS

I am very grateful to Mr. E. Ford, until recently Director of the Millport Marine Station, for his advice.

I am also very grateful to Mr. J. A. Pope of this laboratory for his considerable help with the statistical treatment of the results.

I should like to thank the following of my colleagues:—Mr. B. B. Parrish for his advice and help and Mr. A. Saville for supplying me with the herring larvae caught at sea.

SUMMARY

Counts of myotomes have been made on herring larvae of different parentage and 'race', hatched out in the laboratory at different incubation temperatures ranging from 5·1°C to 14·68°C. Counts were made to the anus and to the end of the body.

The apparent total number of myotomes was found to increase between hatching and absorption of the yolk sac. The anal number does not increase between these stages.

A higher number of myotomes (both anal and total) was found at the lower incubation temperatures than at the higher temperatures. A change in mean by as much as two myotomes for 9 deg. C was recorded.

There was no obvious influence of parental vertebral count on the myotome count of the offspring.

There was no obvious influence of race on myotome count except that the range of counts of spring spawned larvae was wider than that of autumn spawned at the extremes of temperature used. Between 8·5°C and 11·5°C the counts of spring and autumn spawned larvae were very similar.

There was no significant difference in myotome counts of the progeny of an autumn spawning female crossed with a spring spawning male and the progeny of the same autumn spawning female crossed with an autumn spawning male.

A correlation between myotome and vertebral count was found, indicating that results for myotome counts were applicable to vertebral counts as well.

REFERENCES

BLAXTER, J. H. S. 1955. 'Herring rearing.—I. The storage of herring gametes.' Mar. Res. Scot., No. 3.

—— 1956. 'Herring rearing.—II. The effect of temperature and other factors on development.' Mar. Res. Scot. (in press).

BÜCKMANN, A. 1950. 'Die Untersuchungen der Biologischen Anstalt über die Ökologie der Heringsbrut in der südlichen Nordsee.' Helgoländ wiss. Meeresunters., **3**, 171.

DANNEVIG, A. 1948. 'Rearing experiments at the Flødevigen sea fish hatchery, 1943-1946.' J. Cons. int. Explor. Mer, **15**, 277.

DAVIS, F. M. 1936. 'A contribution to the Race Question.' Rapp. Cons. Explor. Mer, **100**, 12.

FAGE, L. 1920. 'Engraulidae, Clupeidae.' Rep. Danish oceanogr. Exped. Medit., **2**, A9.

FORD, E. 1933. 'The number of vertebrae in the herring and its variation.' J. Cons. int. Explor. Mer, **8**, 211.

GABRIEL, M. L. 1944. 'Factors affecting the number and form of vertebrae in *Fundulus heteroclitus*.' J. exp. Zool., **95**, 105.

HEINCKE, F. 1898. 'Naturgeschichte des Herings.' Abh. dtsch. SeefischVer., **2**, CXXXVI+128, XI+223.

HEMPEL, G. 1953. 'Die Temperaturabhängigkeit der Myomerenzahl beim Hering (*Clupea harengus* L.).' Naturwissenschaften, **17**, 467.

JOHANSEN, A. C. 1924. 'On the summer and autumn spawning herrings of the North Sea.' Medd. Komm. Havundersøg., Kbh., **7**, 1.

LEBOUR, M. V. 1921. 'The larval and post-larval stages of the pilchard, sprat and herring from Plymouth district.' J. Mar. biol. Ass. U.K., **12**, 427.

LISSNER, H. 1934. 'On races of herring.' J. Cons. int. Explor. Mer, **9**, 346.

MEYER, H. A. 1878. 'Beobachtungen über das Wachsthum des Herings im westlichen Theile der Ostsee.' Wiss. Meeresuntersuch., **3**, 227.

ROUNSEFELL, G. A. 1930. 'Contribution to the biology of the Pacific herring (*Clupea pallasii*) and the condition of the fishery in Alaska.' Bull. U.S. Bur. Fish., **45**, 227.

ROUNSEFELL, G. A. and DAHLGREN, E. H. 1932. 'Fluctuations in the supply of herring, *Clupea pallasii* in Prince William Sound, Alaska.' Bull. U.S. Bur. Fish., **47**, 263.

RUNNSTRØM, S. 1933. 'Über die Rassenverhältnisse bei dem norwegischen Frühjahrshering . . .' J. Cons. int. Explor. Mer, **8**, 235.

—— 1941. 'Racial analysis of the herring in Norwegian waters,' Fiskeridir. Skr. Havundersøk., **6**, (7), 1.

SCHACH, H. 1939. 'Die künstliche Aufzucht von *Clupea harengus* L.' Helgoländ. wiss. Meeresunters., **3**, 359.

SCHNAKENBECK, W. 1929. 'Entwicklungsgeschichtliche und morphologische Untersuchungen am Hering.' Ber. dtsch. Komm. Meeresforsch., **5**, 19.

—— 1931. 'Zum Rassenproblem bei den Fischen.' J. Cons. int. Explor. Mer, **6**, 28.

TÅNING, Å. V. 1944. 'Experiments on meristic and other characters in fishes.' Medd. Komm. Havundersøg., Kbh., **11**, 1.

—— 1952. 'Experimental study of meristic characters in fishes.' Biol. Rev., **27**, 169.

TESTER, A. L. 1937. 'Population of herring (*Clupea pallasii*) in the coastal waters of British Columbia.' J. Fish Res. Bd Can., **3**, 108.

—— 1938. 'Variation in the mean vertebral count of herring (*Clupea pallasii*) with water temperature.' J. Cons int. Explor. Mer, **13**, 71.

Printed in Great Britain under the authority of Her Majesty's Stationery Office
by Pickering & Inglis, Ltd., Glasgow. Wt. 72471. K6

The following publications issued in the Freshwater and Salmon Fisheries Research Series are in continuation of those previously issued by the Fishery Board ior Scotland, whose functions were transferred in 1939 to the Scottish Home Department:

FRESHWATER AND SALMON FISHERIES RESEARCH SERIES

1950 1. Report of the Supervisory Committee for Brown Trout Research. Price 1s. 6d. (1s. 8d.)

1951 2. Second Annual Report of the Supervisory Committee for Brown Trout Research, 1949-50. Price 2s. 6d. (2s. 8d.)

1952. 3. Third Annual Report of the Supervisory Committee for Brown Trout Research, 1950-51. Price 2s. (2s. 2d.)

1953 4. Fourth Annual Report of the Supervisory Committee for Brown Trout Research, 1951-52. Price 2s. (2s. 2d.)

5. Spawning Migration, Reproduction and Young Stages of Loch Trout (*Salmo trutta* L.). By T. A. Stuart, B.Sc. Price 7s. 6d. (7s. 9d.)

1954 6. Fifth Annual Report of the Supervisory Committee for Brown Trout Research, 1952-53. Price 2s. (2s. 2d.)

1055 7. Sixth Annual Report of the Supervisory Committee for Brown Trout Research, 1953-54. Price 2s. (2s. 2d.)

8. The Movements of Salmon Tagged in the Sea, Montrose, 1948, 1950, 1951. By K. A. Pyefinch and W. B. Woodward. Price 3s. (3s. 2d.)

9. A Review of the Literature on the Biology of the Atlantic Salmon (*Salmo salar* Linn.). By K. A. Pyefinch. Price 4s. (4s. 2d.)

10. Movements of Salmon and Sea Trout, chiefly Kelts, and of Brown Trout Tagged in the Tweed between January and May, 1937, and 1938. By the late G. Herbert Nall, M.A., F.L.M.S., etc. Price 4s. (4s. 2d.)

1956 11. Records of Salmon and Sea Trout caught at Sea. By K. H. Balmain and W. M. Shearer, B.Sc. Price 3s. (3s. 2d.)

12. Seventh Annual Report of the Supervisory Committee for Brown Trout Research, 1954-55. Price 2s. 6d. (2s. 8d.)

13. Observations on the Spawning Runs of Brown Trout in the South Queich, Loch Leven. By W. R. Munro, B.Sc., and K. H. Balmain. Price 4s. 6d. (4s. 8d.)

1957 14. The Effect of Flooding on the Growth Rate of Brown Trout in Loch Tummel. By R. N. Campbell, B.Sc. Price 2s. (2s. 2d.)

(Prices in brackets include postage)

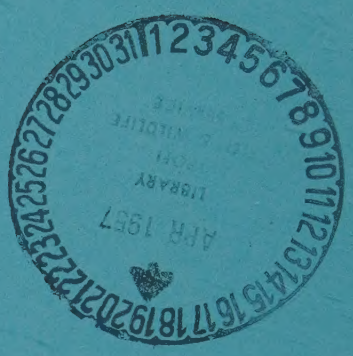
SALMON FISHERIES SERIES

Most of the publications issued by the Fishery Board are now out of print, but limited stocks are still available of some reports. Details of these will be supplied on application.

REPORT ON THE FISHERIES OF SCOTLAND

An Annual Report in narrative form containing the report of the Director of Fisheries Research and dealing generally with Scottish Fisheries, including marine superintendence, salmon fisheries and harbours.

Obtainable from Her Majesty's Stationery Office
at the addresses on page 4 of cover or through any bookseller



Crown copyright reserved

Published by
HER MAJESTY'S STATIONERY OFFICE
To be purchased from
13A Castle Street, Edinburgh 2
York House, Kingsway, London W.C.2
423 Oxford Street, London W.1
P.O. Box 569, London S.E.1
109 St. Mary Street, Cardiff
39 King Street, Manchester 2
Tower Lane, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast
or through any bookseller

S.O. Code No. 49-384